Nuclear Spinodal Fragmentation

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Spinodal multifragmentation in nuclear physics has been reviewed [1]. Considering first spinodal instability within the general framework of thermodynamics, we discuss the intimate relationship between first-order phase-transitions and convexity anomalies in the thermodynamic potentials, clarify the relationship between mechanical and chemical instability in two-component systems, and also address finite systems.

Then we analyze the onset of spinodal fragmentation by various linear-response methods. Using the Landau theory of collective modes in bulk matter as a starting point, we first review the application of mean-field methods for the identification of the unstable collective modes and the determination of their structure and the associated dispersion relations yielding their growth rates. Subsequently, the corresponding results for finite nuclei are addressed and, within the random-phase approximation, and giant resonances in hot nuclei.

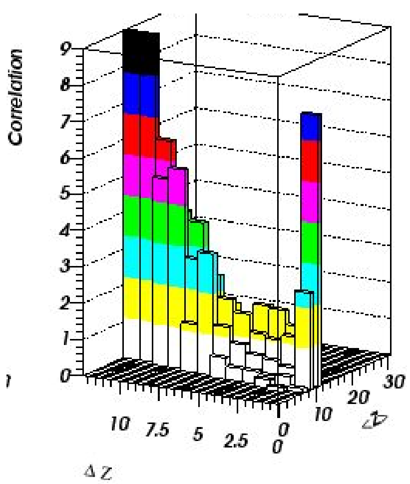

FIG. 1: Size correlations of the N intermediate-mass fragments in central 32 MeV/A Sn + Xe reactions having N=6, as calculated with the Brownian One-Body approximation to the nuclear Bolztmann-Langevin model [2–4].

Turning to the temporal evolution of the unstable systems, discussing first how the dynamics changes its character from being initially linear towards being chaotic and then considering the growth of initially agitated instabilities within the framework of one-body dynamics. We review especially the body of work relating to the Boltzmann-Langevin model, in which the stochastic part of the residual two-body collisions provides a well-defined noise that may agitate the collective modes. We seek to assess the utility of various approximate treatments, including brownian one-body dynamics, and discuss the many possible refinements of the basic treatment.

After these primarily formal or idealized studies, we consider the applications to nuclear multifragmentation and review the various investigations of whether the bulk of the collision zone becomes spinodally unstable. Fragmentation studies with both many-body and stochastic one-body models are discussed and we address the emerging topic of isospin fractionation.

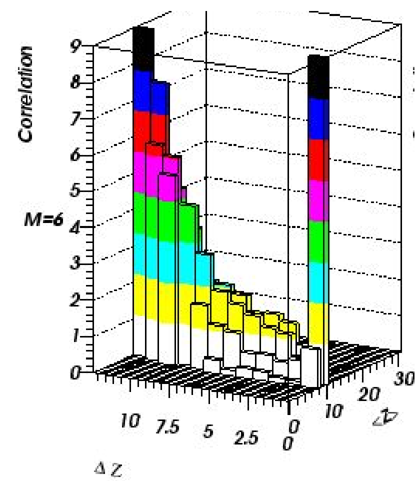

FIG. 2: The IMF size correlations measured by INDRA at GANIL corresponding to the case calculated in Fig. 1 [4].

Contact in then made with experimental data which indicate that the spinodal region is being entered under suitable conditions and we discuss in particular recent results on multifragment size correlations that appear to present signals of spinodal fragmentation. It is demonstrated how various aspects of the data can be understood both qualitatively and quantitatively within the stochastic one-body framework, thus strongly sugggesting that nuclear spinodal fragmentation indeed occurs.

We finally outline perspectives for further advances on the topic and make connections to current progress on related issues.

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